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An introduction to plate leveling

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A four-high leveling system that can handle plate between 0.25 and 6 in. thick and up to 160 in. wide sits on American Steel Products' assembly and testing floor.

Most in metal fabrication know the importance of proper leveling. The processes used to create sheet metal at the mill produce a sheet with trapped stresses, a virtual tug of war of tension and compression. A sheet becomes flat when those forces are at equilibrium across all directions of the plate.

To achieve this equilibrium, coil processors can employ various corrective leveling technologies—tension leveling, temper pass leveling, even stretcher leveling—but roller leveling remains the dominant technology.

Most corrective leveling technologies focus on sheet metal that's 0.25 in. and thinner, but what about plate leveling? Anyone in heavy fabrication, such as large tank fabrication or pressure vessel work requiring heavy rolling, knows the challenges when a plate being cut or formed releases stress. The process becomes less predictable. But technology to level plate—sometimes up to 6 in. thick—can help make heavy fabrication much more predictable, faster, and less costly.

Historical Context

The demand for plate leveling goes back decades. Plate several inches thick, designed for ships and submarines going back to before World War II, needed to be flat before fabrication began, hence the need for leveling, which usually occurred at the mill. Over the years plate leveling became more critical as the materials became more complex. Tanks and ships are prime examples, as well as other products fabricated over the years for the oilfields, natural gas plants, the water utility industry, food processing plants, bridge building, and elsewhere.

Some areas of food and chemical processing use clad plate, incorporating a thick base metal section of carbon steel and a cladded layer of stainless steel around the inside diameter, to prevent corrosion and chemical reactions to acid on the inside wall while allowing components to be welded to the carbon steel on the OD. Some tanks are lined with rubber or glass. Large-diameter pipe made of high-strength plate, critical for offshore drilling, also needs leveling.

A few manufacturers work in the extreme thicknesses of stainless steel, even plate consisting of multiple alloys fused together. A company called Dynamic Materials Corp., for instance, fuses 0.25-in.-thick stainless with carbon steel that's up to 3 in. thick. Not surprising, given its stock ticker—BOOM—the company fuses the stainless to carbon steel in an underground chamber through a unique form of explosion welding. All this creates extraordinarily strong, thick plate that, before being cut and formed in a fabrication shop, needs to be leveled.

In all this work, 0.25 in. is considered thin. Most of this plate is thicker, and much of it is multiple inches thick. Put a raw, 3-in.-thick plate—full of uneven, trapped stresses—through a three-roll or four-roll bending roll, and there's little chance you'll produce a perfect cylinder with ease, with the prepped edges meeting just at the right place for subsequent welding.

Regardless of the process, if an operator starts with a plate that's bowed in the middle or has any number of other shape defects, that process is likely to become more arduous and much more expensive. It's why an operator starts by using a long (8 feet, for instance) straight edge to ensure a plate is level in all directions before starting any forming or fabrication.

Industry plate flatness standards specify a certain degree of flatness; 0.25-in. variance over 8 ft. is a common specification. But many plate fabrication operations require much tighter flatness tolerances, sometimes down to a small fraction of the industry standard. This is where precision plate leveling comes into play.

Unleveled Plate

If a fabricator or other manufacturer purchases plate that hasn't been leveled, the person receiving the material might notice the shape defects immediately. These include crossbow across the width and a sweeping curve along its length.

4340 alloy plate, 150-KSI yield strength, undergoes a leveling process.

Massive, precision-controlled hydraulic cylinders determine the penetration depth of individual rolls. This system can level plate up to 6 in. thick and exert up to 6,000 tons of separating force.

As with sheet metal, plate shape defects are a side effect of steelmaking, evidence of the stresses induced into the material by the rolling mill and subsequent cooling. The temperatures aren't uniform. Plate is rolled at its hottest to start, and it's quenched to make it a certain strength. But quenching does not result in a perfectly uniform, homogenous yield strength throughout the entire plate. Volumes of metallurgical literature have been written on the subject, of course. But generally, the nature of steelmaking and how heat dissipates through the material affects the microstructure, its internal stresses, and, ultimately, the resulting shape.

Plate Leveling Basics

If you know how a roller leveler works sheet metal, you have an idea of how a heavy-duty plate leveler works plate. Most roller levelers for gauge material have large alloy backup rolls behind the main alloy rolls; for instance, a four-high machine has backup rolls with large roller bearings on the top and bottom. The design allows the rolls to deflect less and allows for fine adjustments to produce a uniform, flat material. The sheet enters through initial rollers that have the greatest penetration, following what's known as the differential path around alternating, or staggered, upper and lower rolls.

Plate levelers apply up to 6,000 tons of separating force, or the vertical force applied by the rolls. In fact, heavy-duty plate levelers apply forces that surpass those applied even by the rolling mills that produce the steel. All that force comes from powerful cylinders that apply 10,000 pounds of hydraulic pressure per square inch.

Most plate levelers are four-high machines, with significantly larger backup rolls behind the work rolls. The operation of these machines bears some resemblance to roller leveler operation, but in many ways it's a different animal, mainly because of the extreme forces and the range of yield strengths in different areas across a given plate. The yield can change from one area of the plate to another, and in all directions. This creates the need for adjustment, and this is where plate leveling stands apart from conventional roller leveling.

To adjust a roller leveler, an operator can adjust a flight of rolls tied together on the same plane. This wouldn't work under the parameters necessary in plate leveling, which often requires extreme forces and significant differences in penetration from one roll to the next. Having work rolls connected in a flight limits the material penetration the operator can achieve.

To obtain the maximum penetration and perform the fine adjustments that plate leveling demands, each roll's adjustment is actuated by a dedicated, precision-controlled hydraulic cylinder, with each roll adjustment measuring ±0.001 in.

Because the material yield can vary significantly at different locations along the plate's length and width, the ability to adjust is critical. Some plate levelers use in-process laser measuring devices. The lasers give the machine a real-time view of the material condition. An unexpectedly large change in yield strength will cause a specific roll setting to affect the material shape in a different way; if the laser measures the material position outside a certain tolerance window, the leveling operation can compensate accordingly.

In a typical plate leveling setup, bending rolls induce uniform bends in the positive and negative direction. The first few sets of rolls generally have deep penetration to remove the distortion and equalize the stress—essentially "getting the kinks out" of the plate—with the last three roll sets controlling the final straightness.

A plate doesn't always flatten entirely after just one pass through the machine. In some cases, it is sent through the rolls once, reversed, and then sent through again. Quite often the plate emerges from the leveler after the first pass with a sweeping upward curve. In a sense, the leveler replaces a multitude of shape defects with just one, a uniform curvature, which then can be eliminated by reversing the plate through the rollers and sending it through again to perform the final leveling. Typically, the operator maintains the same roll settings for both the first roll pass and the reverse pass. It can be the third pass where the operator makes the final, critical changes.

The operator reviews a book that gives him the digital settings for a specific material yield and thickness. But the operator needs to inspect the material carefully as it emerges from the first pass. If the yield varies significantly—and it can, simply because of how the plates are made at the mill, including the quenching process—the operator might need to make significant adjustments to the leveler settings on the final pass (or passes).

A plate with crossbow enters its first pass on a four-high plate leveler with individual roll adjustment.

Avoiding Expensive Scrap

Occasionally the operator needs to repeat this process two or three times before the plate emerges perfectly flat in all directions. That said, usually the operator completes the leveling process in just three passes—forward, backward, and then forward again through the machine.

It's a balancing act, because a plate leveling operator never wants to overwork the plate. Overwork the material and its properties can change to such a degree that subsequent fabrication becomes difficult or impossible. And considering the size and value of the material, overworking it in a plate leveler can create very expensive scrap. This is why the ability to fine-tune the roll settings, particularly in the final work rolls, is so critical.

Such fine-tuning at the leveler can prevent extraordinarily expensive scrap further downstream. In heavy fabrication, a single workpiece can have a six-figure price tag, even before the fabricator has put any value into it. The flatter that plate is, the more consistent downstream operations become, and the more profitable and successful a heavy fabricator can be.

Ford Cauffiel is president of American Steel Products Co., a division of Cauffiel Industries, 3171 N. Republic Blvd., Toledo, OH 43615, 419-843-6051, www.americansteel.com.